DISCUSSION DRAFT 5-19-08

Task: Develop an updated hydrodynamic, sediment transport and PCB transport and fate model at the New Bedford Harbor Superfund Site.

Sponsor: US EPA Region 1 and EPA Superfund Headquarters

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I Introduction

Region 1 of the U.S. Environmental Protection Agency (EPA) is interested in updating the physical, chemical, and biological modeling that was performed at the New Bedford Harbor (NBH) Superfund Site by Battelle around 1990. There are two primary components to this modeling: 1) the hydrodynamic, sediment and contaminant transport modeling and 2) the food-chain modeling. In this proposal, we describe the effort to update the hydrodynamic and contaminated sediment model which can then be used to provide the water column and sediment bed PCB concentrations that drive the foodchain model.[2] In this context, updating refers to using state-of-the-art sediment and contaminant transport models which represent more transport processes and represent those processes more accurately than models available in the late 1980's and early 1990's. The tremendous increase in computing power since that time will be capitalized on to 1) improve upon the representation of the harbor geometry and bathymetry through the use of a finer numerical grid in both the horizontal and vertical dimensions, and 2) as is discussed below, to expand the modeling domain Bay (for the hydrodynamic modeling) to include Buzzards Bay.

The importance of modeling sediment transport at this site is due to the dominating presence of highly chlorinated PCBs, mostly Aroclor 1242 and Aroclor 1256. These PCB mixtures preferentially adsorb to organic matter in surface waters, both as POC on sediment particles suspended in the water column and deposited on the bed, and DOC in the water column and in the pore water of the bed. As such, simulation of PCB transport at NBH also requires the simulation of the fine-grain sediment that is the dominant type of sediment in both the inner and outer harbor. Accurate simulation of fine-grain (i.e., cohesive) sediment transport requires the measurement of site-specific properties that govern the transport of cohesive sediment in surface waters.

Along with using improved models, new methods for measuring site-specific erosion rates and critical shear stresses of resuspension of fine-grain dominated sediments (as are present in NBH) have been developed since the early 1990's. Most notable is the

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[1] member of EPA's Contaminated Sediments Technical Advisory Group (CSTAG)
[2] It is anticipated that Lawrence Burkhard, EPA Office of Research and Development (ORD) with assistance from Karl Gustavson, will perform the food-chain modeling.

Sedflume, which can be used to measure gross erosion rates and critical resuspension shear stresses with depth in a sediment core collected at the site. We are proposing that a Sedflume study be conducted in order to more accurately predict erosion rates of sediment in NBH. A second critical need in modeling contaminated sediment transport is measurement of the site-specific settling velocities of fine-grain sediment flocs. The settling velocities of flocs are functions of, among other factors, concentrations of suspended clay, silt and organic particles; turbulence intensity; salinity; and clay mineralogy. A field study to measure floc settling velocities is also a proposed component of this modeling project.

The Battelle hydrodynamic, sediment and contaminant transport model (henceforth called the Battelle model) and the application of this model to NBH contained numerous assumptions and limitations that greatly increased the uncertainties of the results used in the subsequent foodchain modeling, and as a consequence, increased the uncertainties associated with the latter modeling. Some of these assumptions and limitations are listed below:

- Temporally and spatially constant eddy viscosities and eddy diffusivities were used in the Battelle model.
- Wind waves were assumed not to propagate into the harbor from outside the modeling domain.
- The modeling domain is too small to accurately represent the propagation of the incident and reflected tidal waves within the harbor.
- Sediment bed is limited to one 4-cm layer.
- Parameters used to calibrate the sediment transport module were the mean grain size for noncohesive size fractions, critical shear stresses for each type and size fraction, and erodibility coefficients for cohesive sediments.
- Primary calibration parameter for the contaminant transport model was the bed partitioning coefficients.
- Surface sediment data from the literature are used to represent the properties of the sediment bed.
- Diffusion of dissolved PCBs in the bed is not represented.
- The percentage of organic matter on sediment particles and its effect on adsorbed and dissolved PCB transport is not represented.
- Limited sensitivity and uncertainty analyses and model calibration were performed.
- No model validation was performed.
- Model results from 95-day model simulation using synthetic hydrodynamics linearly extrapolated in two-year increments to estimate fate of the PCBs over 10 years.
- The synthetic 95-day hydrodynamics were generated by piecing together the hydrodynamics computed for the following two 24-hour simulations: fair weather case with northerly winds ranging from 2 to 10 m/s, and a storm event case with southerly winds of 1 to 15 m/s. Both cases were forced by a M2 tide applied at the open water boundary. The synthetic hydrodynamics used to force the sediment and contaminant transport model consisted of the following sequence of the two cases: 31 days of the fair weather case, 1 day of the storm event, 31 days of the fair weather case, 1 day of the storm event, and 31 days of the fair weather case.

Most of these limitations and assumptions will not be used in performing the proposed PCB transport and fate modeling study for New Bedford Harbor. The modeling strategy proposed for used by ERDC in performing this modeling study is described below.

II Modeling Strategy

2.A Modeling framework

The modeling framework must address aspects of system hydrodynamics, suspended solids transport, and PCB kinetics within the water column and bed sediments. Selection of a specific model (or models) requires consideration of multiple factors. These include:

- Management expectations of model results
- Acceptability of previous model applications
- Data required for application
- Computational requirements
- Duration of model application period
- Compatibility of model outputs with input requirements of food-chain model.

Selection of a single model that ideally suits all requirements is impossible, especially since some factors appear mutually exclusive. For example, computational requirements for an extremely detailed model may preclude necessary simulations of the lengthy time periods necessary to validate a PCB model.

The team will inspect available PCB model frameworks with emphasis on two proven systems. These are the Environmental Fluid Dynamics Code (EFDC) applied to the Housatonic River, among other locations, and the Delaware River PCB Model (DELPCB) which is an enhanced version of the EPA Water Analysis Simulation Program (WASP). EFDC incorporates its own hydrodynamic model. DELPCB requires application of a separate hydrodynamic code for which an available finite-volume code, FVCOM, will be considered. Following inspection of these and, perhaps, other relevant frameworks, the team will make a recommendation based on the considerations listed above. Final model selection will be made in concert with the sponsor.

2.B Modeling procedure

We expect the modeling procedure will incorporate the following elements:

1) Develop computational grid for NBH that extends out into Buzzards Bay. The grid will be finer in both the inner and outer harbor than that used in the Battelle modeling study.
2) Investigate developing open water boundary conditions using hydrodynamic model of the New England coastal sea (FVCOM) developed by Dr. Changsheng Chen at UMass-Dartmouth.

3) Setup, calibrate and validate the hydrodynamics computations for the chosen modeling domain.
4) Setup, calibrate and validate the suspended solids computations.
5) Setup, calibrate and validate PCB transport and fate computations.
6) Run long-term (i.e., multi-year simulations) to generate time series of PCB water column concentrations and sediment bed concentrations needed to perform the foodchain modeling.
7) Prepare model output in a form suited for food-chain modeling. Food-chain modeling will be conducted by Lawrence Burkhard, EPA Office of Research and Development based on input from the site's remedial project managers.

III Field Study

Cohesive sediment processes such as erosion and settling are influenced by a host of physical, chemical, and biological factors such as: sediment mineralogy, water chemistry, organic content, hydrodynamic stresses, and biological activity. The present state of knowledge does not permit prediction of cohesive sediment processes based on these known influences (much less so for the unknown influences). Consequently, site-specific measurements are required to represent cohesive sediment processes in numerical models.

Since 1990, significant advances were made in field measurement of cohesive sediment processes. Advances in techniques, instrumentation, and analysis permit definition of processes with much greater certainty than available in 1990.

3.A Sedflume study

Sedflume is a device developed in the mid 1990s for measurement of cohesive sediment erosion from cores taken from the sediment bed or reconstructed in the laboratory. Sedflume consists of a rectangular cross-section duct with bottom-located test section through which a 10-cm diameter core is inserted. Shear stress is applied to the core surface by user-variable flow through the duct. As sediment is eroded from the core surface, the user advances the core such that the core surface is flush with the bottom surface of the duct. Erosion rate is determined as the average rate of core advance over the testing interval. See McNeil et al.[3] for additional description and details of Sedflume.

For this study, Sedflume, approximately fifteen 30- to 50-cm cores will be extracted from upper and lower New Bedford Harbor. Erosion experiments will be conducted on site to minimize sample disturbance. Core extraction and Sedflume erosion experiments will be conducted following standardized procedures to ensure proper handling, sample preparation, and data quality. Vessel support for core collection is assumed to be provided by EPA ORD-Narragansett. It is proposed that supply and discharge waters (and eroded sediments) for the erosion experiments be taken from and returned to upper

[3] McNeil, J., Taylor, C., and Lick, W. (1996) Measurements of erosion of undisturbed bottom sediments with depth. *Journal of Hydraulic Engineering*, 122(6): 316-324.

New Bedford Harbor without treatment. Sediment separation and treatment is possible, but increases both time and cost to conduct the erosion experiments. ERDC will coordinate with appropriate organizations to secure a site for the Sedflume mobile laboratory.

3.B Settling velocity study

The Particle Imaging Camera System (PICS) is an ERDC-developed system for in-situ measurements of cohesive sediment settling velocities. PICS collects digital video of particle settling within a small settling column within the water column. Sample collection, optical and lighting design, and image acquisition were designed to produce high-quality, in-situ image sequences. PICS consists of a 1-m long, 5-cm inner diameter settling column with a mega-pixel digital video camera and strobed LED lighting. The settling column is equipped with two pneumatically controlled ball valves at the column ends which permit sample capture and a third pneumatic actuator for rotating the column from horizontal to vertical orientation for image acquisition. Image sequences collected by PICS are analyzed with automated particle tracking software to produce size, settling velocity, and density (estimated) distributions of particles suspended at the sampling location. Additional instrumentation deployed with PICS include Laser In-Situ Scattering and Transmissometry (LISST-floc), CTD, and pump sampling capabilities.

PICS will be deployed at two 12-hour anchor stations during which hourly or half-hourly casts of the system will be used to quantify tidal variability in suspended floc characteristics and settling velocities will be determined. Additionally, a roving survey spanning two days and covering upper and lower New Bedford Harbor will be conducted to document spatial variability in floc characteristics. Vessel support for the PICS system is assumed to be provided by EPA ORD-Narragansett.

3.C Other studies or data needs may be required (hydrodynamic, chemistry, or organic carbon partitioning)

Hydrodynamic. Availability of hydrodynamic data (tides and currents) for model calibration and verification have not been assessed. If data availability or quality are determined to be insufficient for model assessment, it is proposed that appropriate data are collected during the field experiments described in 3A-B. An Acoustic Doppler Current Profiler (ADCP) survey could be efficiently and cost-effectively be combined with the PICS experiment outlined in 3B. In this case, a hull-mounted ADCP would be deployed and operated for both the 12-hour anchor stations and roving surveys. No additional vessel time and minimal additional personnel costs are associated with collection of these data.

Draft Project Outline and Time Estimate

Component	Hours
1. Historical data review and collection a. bathymetry b. hydrodynamics c. water PCB concentrations d. sediment PCB concentrations e. sediment physical characteristics, including erosion properties f. review of previous modeling efforts and outputs	180
2. Model design and parameterization	270
3. Data gaps analysis	90
4. Additional data collection (based on data gaps analysis)	560
5. Model calibration	360
6. Model validation	270
7. Run model scenarios a. baseline b. management action 1 c. management action 2 d. management action 3	270
8. Model and results documentation	180
Total	2,180

<u>Budget:</u>

Labor hours, assuming $125 per hour: $272,500

Field data collection (component 4): $28,500

Travel and publication costs: $40,000 K

Total: $341,000

Draft Project Schedule:

	Month													
Component	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1. Review of existing data														
2. Model setup														
3. Data gaps analysis														
4. Additional data collection & analyses														
5. Model calibration														
6. Model validation														
7. Run model scenarios														
8. Model and results Documentation														